Early Mathematical Knowledge: Deficits Among Low-Income Children And Insights Into Prevention

Just as mathematical ability begins to form in early childhood, so, too, does the knowledge gap separating low-income children from their more affluent peers, who generally enter school with much greater math knowledge.

This gap is troubling given that early deficits in mathematical knowledge can have profound implications for future learning. Researchers report, for example, that children's knowledge of mathematics in kindergarten predicts their scores on achievement tests during the elementary grades and on into high school.[1]

One the many areas of math that young children from low-income backgrounds struggle with is number sense. Number sense is about understanding numerical magnitudes – being able to choose numbers whose magnitudes are close to the correct values. Recent studies suggest there are simple ways to promote early development of number sense that could be widely used to help low-income preschoolers improve their overall mathematical knowledge.

After looking at how children's understanding of numerical magnitudes develops, Carnegie Mellon University researcher Robert Siegler and colleagues applied their analysis to design and test a brief, inexpensive activity that resulted in improving a wide range of numerical skills and knowledge. This report examines the problem of early math deficits among low-income children, and discusses the activity they developed and its implications.

Early Mathematical Deficits

Children from low-income families are more likely to begin school with much less math knowledge than children from middle-class and wealthier backgrounds. This gap is seen across several fundamental math tasks, including counting from one, counting up or down from numbers other than one, recognizing written numerals, adding, subtracting and comparing the magnitudes of numbers.[2, 3]

Early deficits in mathematical knowledge can have long-lasting consequences. In general, a child who starts out behind stays behind. Achievement test scores provide evidence of the math achievement gap between low-income students and their more affluent peers.

This gap, for example, was identified by the 2003 Mayor's Commission on Public Education as one of the challenges facing the Pittsburgh Public Schools. Test scores showed that only 29% of low-income students in the city public school were proficient in math during the 2001-2002 school year.[4] Statewide, 52% of all students were proficient in math that year. The commission's report defined low-income students as those whose family income fell below poverty levels, as well as those with family incomes low enough to qualify for the federal free and reduced lunch program. About 60% of the students enrolled in the Pittsburgh Public Schools in 2001-2002 fell into these categories.

Similar gaps are seen throughout Pennsylvania. Despite general improvement in statewide academic proficiency scores during the 2007-2008 school year, students who attended school in disadvantaged communities continued to struggle, accounting for 68% of those whose math and verbal scores fell "below basic," which is the lowest category on the Pennsylvania System of School Assessment.[5]

Learning Support

Research suggests that the mathematical knowledge gap reflects a difference in the learning support children receive from their parents and others. Studies have found, for example, that middle-income parents engage in a wider range of math activities with their children and do so more frequently than do parents in low-income households.[6, 7]

Studies also point out the benefits of such practices in the home: Children whose parents engage in more numerical

activities generally possess greater math knowledge.[8]

Such findings underscore the value of designing activities to improve the understanding of numbers that can be widely used among low-income preschoolers who are less likely to be exposed to adequate early math support at home.

Number Sense

Number sense is one area of mathematical knowledge found to be particularly weak among low-income children. Definitions of number sense cite broad and varied types of knowledge, including skill at immediately identifying the numerical value associated with small quantities, facility with basic counting, and understanding how to compose and decompose whole numbers.[9]

Siegler and colleagues focused on a single, important process in defining number sense as the ability to approximate numerical magnitudes.[10] Such approximations can be applied to numerical operations, such as answering the question: "About how much is 12 x 55?" Another common application is approximating objects, events or sets. For example, "How many people were at the football game?"

The researchers found estimation tasks using a number line to be an advantageous way to investigate children's number sense. Studies suggest that math achievement correlates with children's ability to correctly space numbers on number lines.

Young children typically have difficulty doing that, but improve with age and experience. For example, even preschool-age children who can count perfectly from 1 to 10 do not understand the rank order of the numbers' magnitude.[11] Even after they learn the rank order of numbers' magnitude, they do not immediately show the magnitudes as increasingly linear.

Learning Experiences

Such findings led researchers to look at what experiences tend to lead children to represent the magnitudes of small, verbally stated or written numerals as increasingly linearly.

Counting experience in early childhood is believed to contribute. However, children often are able to count in a numerical range for a year or longer before they are able to make linear representations of numerical magnitudes in that range,[12] which suggests other experiences are also involved.

One activity seen as ideally suited for producing such representations is playing board games with linearly arranged, consecutively numbered, equal-size spaces, such as the popular commercial children's game, Chutes and Ladders. That game's board has numbers up to 100, each having its own square of equal size, which are arranged in a grid.

Such games offer children cues to the order and the magnitude of numbers: The greater the number in a square, for example, the greater number of moves the child makes with the token or the greater distance the child has moved the token. The games also give children practice in counting and in identifying numerals.

A Simple Board Game

Researchers tested the notion that a numerical board game could improve mathematical knowledge by randomly assigning 4- and 5-year-olds from Head Start centers to one of two simple board games they designed.

Each game had 10 squares of equal size horizontally arranged. One game, however, had the numbers 1-10 listed consecutively from left to right, while the other game had colored squares without numbers. Children spun a spinner and moved their token the number of spaces shown on the spinner. They were also asked to say the numbers or colors on the spaces they moved the token through.

Children took part in four sessions that lasted 15-20 minutes each and were spread over a two-week period. The games themselves lasted only about 2-4 minutes each.

In addition, children were given a number line estimation task with numbers 1-10 before and after they played the game. For comparison, the same number line estimation task was given to a group of middle-income children who did not play either version of the board game.

The idea was to use the task to measure any change in the estimating abilities of the Head Start children who played the board game and to see how their performance compared with that of middle-income children who, studies suggest, are exposed to more math-related activities at home. In fact, a survey taken in a follow-up study showed that middle-income children reported twice as much experience playing board games than children from low-income backgrounds.

Broad Gains Reported

The brief experience of playing the numbered board game resulted in significant gains in how Head Start children performed on the number line estimation task. Before children played the numbered board game, the best-fitting linear function accounted for an average of only 15% of the variance in individual children's scores. After they had experience playing the game, the best-fitting linear function accounted for an average of 61% of the variance.

That improvement brought their performance on the estimation task up to levels seen among the middle-income children who had not played the game, but as a group tend to have much more experience with board games and other math activities at home.

On the other hand, playing the board game that used

color squares did not affect the number line estimation performance of the Head Start children who were assigned to it. The best-fitting linear function accounted for an average of only 18% of the variance in their estimates on both the tests given before playing the game and the tests given afterward.

In a later study, researchers looked at the range of mathematical knowledge that 124 Head Start children gained by playing the numbered board game and whether those gains could be expected to last.

To investigate the range of math knowledge, they compared the effects of playing both the numbered board game and the color game on the children's understanding of the numbers 1-10 in tasks that included making estimates with a number line, comparing magnitude, identifying numerals and counting. These tasks were done immediately before and after children played the games. Researchers followed up those tests by having the children perform the tasks again nine weeks after they had completed their last game session.

Again, playing the numbered board game produced wide benefits for the Head Start children who were assigned to do so. The accuracy of their number line estimations increased from pre-test to post-test, and their performances on the magnitude comparison, numeral identification and counting tasks also improved after having had the experience of playing the game.

The group of children who played the board game with colored squares showed no change in their performance on the tasks used to assess mathematical knowledge.

In all cases, the Head Start children who were assigned to play the numbered board game showed improvements that lasted over the nine-week follow-up period, while the children who played the color board games failed to demonstrate any gains, either immediate or delayed.

Such findings add to a growing body of evidence that suggests improving the numerical understanding of low-income preschool-age children leads to broad, rapid learning. In this case, the learning tool was a simple, inexpensive board game that could be widely used to help close the mathematical knowledge gap between low-income children and their more affluent peers.

References

Siegler, R.S. (2009). Improving the numerical understanding of children from low-income families. *Child Development Perspectives, 3*(2), 118-124.

This Special Report is based on the publication cited above. It is not intended to be an original work but a summary for the convenience of our readers. References noted in the text follow:

[1] Duncan, G.J., Dowsett, C.J., Claessens, A., Magnuson, K., Huston, A.C., Klebanov, P., et al. (2007). School readiness and later achievement. *Developmental Psychology, 43*, 1428-1446.

[2] Ginsberg, H.P., & Russell, R.L. (1981). Social class and racial influences on early mathematical thinking. *Monographs of the Society for Research in Child Development, 46*(6, Serial No. 69).

[3] Jordan, N.C., Kaplan, S.C., Olah, L.M., & Locuniak, M.N. (2006). Number sense growth in kindergarten: A longitudinal investigation of children at risk for mathematics difficulties. *Child Development, 77*, 153-175.

[4] Mayor's Commission on Public Education. (2003). *Keeping the Promise: The Case for Reform in the Pittsburgh Public Schools*. Full report, September 2003, 24-25. www.aplusschools.org/pdf/KeepingthePromise-Full2.pdf

[5] Pennsylvania Department of Education. 2008 Student Achievement Fast Facts. http://www.pde.state.pa.us/a_and_t/lib/a_and_t/AYP_PSSA_final_fast_facts_2008.pdf

[6] Clements, D.H., & Sarama, J. (2007). Effects of a preschool mathematics curriculum: Summative research on the Building Blocks Project. *Journal for Research in Mathematics Education, 38,* 136-163.

[7] Starkey, P., Klein, A., & Wakeley, A. (2004). Enhancing young children's mathematical knowledge through prekindergarten mathematics intervention. *Early Childhood Research Quarterly, 19,* 99-120.

[8] Blevins-Knabe, B., & Musun-Miller, L. (1996). Number use at home by children and their parents and its relationship to early mathematical performance. *Early Development and Parenting, 5*, 35-45.

[9] National Mathematics Advisory Panel. (2008). *Foundations for success: The final report of the National Mathematics Advisory panel*. Washington, DC: U.S. Department of Education.

[10] Siegler, R.S., & Booth, J.L. (2005). Development of numerical estimation: A review. In J.I.D. Campbell (Ed.), *Handbook of mathematical cognition* (pp. 197-212). New York: Psychology Press.

[11] Ramani, G.B., & Siegler, R.S. (2008). Promoting broad and stable improvements in low-income children's numerical knowledge through playing number board games. *Child Development, 79*, 375-394.

[12] Le Corre, M., Van de Walle, G., Brannon, E.M., & Carey, S. (2006). Re-visiting the competence/performance debate in the acquisition of the counting principles. *Cognitive Psychology, 52,* 130-169.

Announcements. . .

Parenting Guide Series Available From OCD

The University of Pittsburgh Office of Child Development is offering a series of easy-to-use parenting guides offering information and advice on 50 parenting topics. These guides are available free of charge to parents and organizations, agencies and professionals who work with children and families.

The You & Your Child parenting guide series, written and edited by the University of Pittsburgh Office of Child Development, covers topics ranging from how to deal with children's fears, finicky eating habits, and aggressive behavior to getting a child ready to read, setting rules, and coping with grief.

Each guide is based on current parenting literature and has been reviewed by a panel of child development experts and practitioners. The series is made possible by the Frank and Theresa Caplan Fund for Early Childhood Development and Parenting Education.

To receive a printed set of all 50 guides by mail, send a request along with your name, organization, mailing address and telephone number to:

Parenting Guides
University of Pittsburgh
Office of Child Development
400 North Lexington Avenue
Pittsburgh, PA 15208.

The You & Your Child parenting guides are also available on the OCD website as portable document files at: www.education.pitt.edu/ocd/family/parentingguides.asp.